Sea Technology 44(9):50-55/2003

GEOMAR Landers as Long-Term Deep-Sea Observatories

Applications and Developments of Lander Technology in Operational Oceanography

By Dr. Olaf Pfannkuche
Principal Scientist
and
Dr. Peter Linke
Senior Scientist
GEOMAR Research Center for Marine Geosciences
Kiel, Germany

A fleet of six GEOMAR modular landers lined up for deployment.

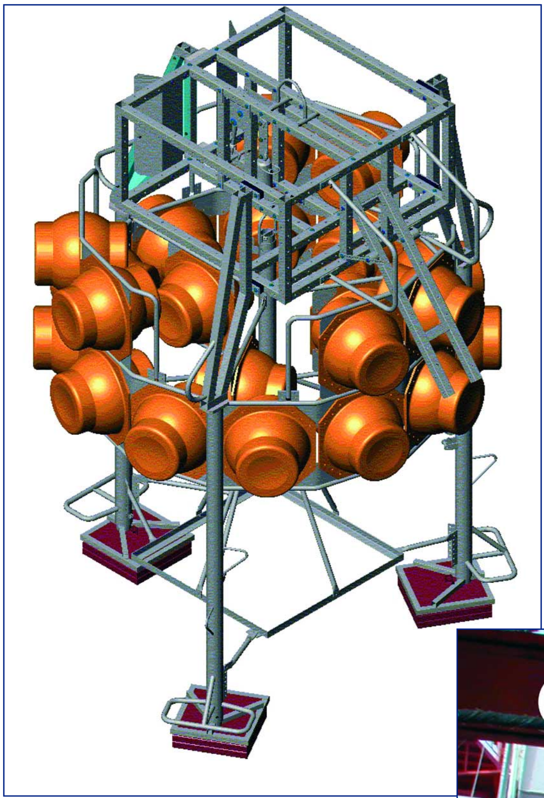
Landers, as autonomous instrument carrier systems, are used to study processes at the benthic boundary layer. They are usually deployed on the seafloor at depths of several hundred to 6,000 metres beyond the reach of remote sensing and conventional systems.

After reaching the seafloor in a free-fall mode, an onboard command system starts the deep-sea experiment. At the end of the mission an acoustic command releases the ballast weights, and the lander rises by the virtue of its positive buoyancy to the sea surface.

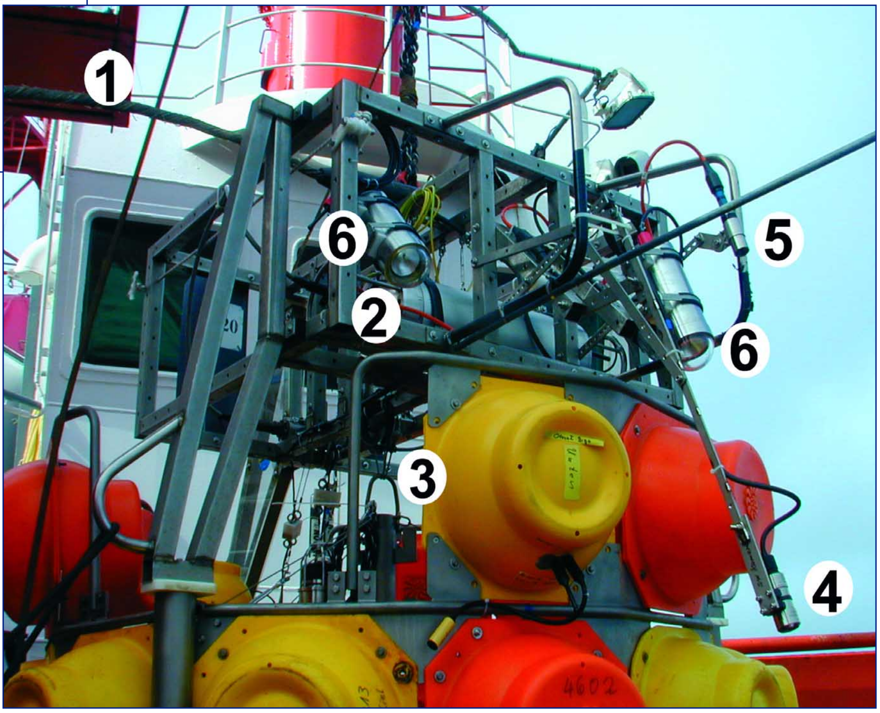
The first steps toward the development of successful deep-sea autonomous vehicles were taken in the United States in the late 1970s by the development of the free vehicle grab respirometer (FVGR)[1] and Manganese Nodule Project (MANOP) Lander.[2]

The first German lander system was successfully deployed at a 4,500-metre depth in 1986.[3] In the early 1990s, there were already about 30 lander systems in operation.[4] Also in the 1990s, the technological lead of international lander development shifted to Europe, which was benefiting

Reprinted from **Sea Technology**



(Left) A sketch of the GML-configuration with floats, ballast and launching device. The central platform potentiates the incorporation of a large spectrum of scientific payload.



(Bottom) The launcher connected to (1) the vessel's cable, (2) carrying the telemetry, (3) the electric release, (4) the survey, (5) the down-looking video camera and (6) the floodlight.

from the European Union Marine Science & Technology (MAST) Programmes, specifically the Autonomous Lander Instrument packages for Oceanographic Research (ALIPOR) Programme.[5]

GEOMAR Lander System

Lander systems are now used as platforms for a wide spectrum of oceanographic applications. They must work autonomously for periods of up to six to 12 months. This requires robust design and manufacturing as mechanical and electronics systems must withstand worldwide transportation in containers and deployment from an arbitrary ship to the deep ocean at pretty rough sea states. Once on the seafloor, the systems must work without human input. Instruments and software systems must be robust because system crashes, similar to those one may have experienced with a desktop PC, cannot be tolerated.

GEOMAR Research Center for Marine Geosciences has 10 years of experience working with the design and manufacture of deep-sea landers in close cooperation with local small- and medium-sized enterprises. The center presently operates a suite of six modular design landers as a universal instrument carrier for benthic boundary layer observatories.

The GEOMAR Modular Lander System (GML) is based on a tripod-shaped universal platform that can be easily dismantled for transport, provides a flexible float arrangement and an open instrument platform to carry a wide range of scientific payloads. The frame is made of stainless steel or titanium, the later version for long-term endurance in corrosive environments and weight reduction. The GML carries a floatation unit with up to 33 17-inch glass floats. Some of these floats are used as instrument housings for an Argos beacon and for the power supply (NiCd batteries with up to 12V/56Ah) for the various instruments. Three stacks of iron squares (150 kilograms each) are used as ballast weights. They are released by paired acoustic transponder releasers upon acoustic command. For spotting and recovery, the lander is equipped with a radio beacon, strobe light and flag.

To facilitate the recovery procedure, a small float with a six-metre-long floating recovery line is released simultaneously with the ballast weights which can then be salvaged to lift the floating lander from the sea surface onboard with the ship's crane. The float is retained in a small container during deployment to prevent interference with instrumentation.

Another modular feature lies in the use of a universal microcontroller board based on the Infineon C164CI controller. The design goal has been to come up with an easily programmable, flexible platform with decentralised design to minimise the effect of failures of single components, low power consumption, timed control of DC-motors and enough memory to be used as dataloggers. The solution was a small printed circuit board (PCB) that carries a commercial microcontroller-board and some relay-based drivers for the various DC-motors. Standardized and exchangable motors are used for any mechanical movement on the landers. They deliver a transistor-transistor logic (TTL) signal that corresponds to their revolution. This signal is galvanically isolated and evaluated by the microcontroller board. The shaft of the motor is sealed by a specially developed O-ring construction. The PCB is mounted in a titanium pressure housing that has six to 12 connectors and is pressure-resistant down to 6,000 metres. The programs for the microcontroller were written with a commercial C-compiler. The code of the program can be transferred serially via RS-232. The power consumption is kept very low by not using stand-by modes; instead the complete system is powered down and then restarted by a real-time clock alarm. The times of events are preprogrammed with a laptop computer and a Windows-based interface (in the lab or on deck of the ship). A magnetic "wizardstick" and a reed-switch finally start the system.

Targeted Lander Deployment

Landers are typically deployed in the conventional free-fall mode, where the lander is released from the ship at the sea surface. It will land on the seafloor depending on water depth and the ambient hydrographic regime in a radius of hundreds of metres to more than a kilometre beneath the ship's position. This mode of deployment is still used for investigations on abyssal plains or other rather uniform seafloor settings.

However, many scientific objectives addressing specific geomorphological features such as cold seeps, mud mounds or particular benthic communities require a targeted and soft lander deployment. For these requirements, Dr. Peter Linke developed the concept of a targeted lander deployment with a special launching device connected to the ship's coaxial or hybrid fibre optical cable. This launcher carries the telemetry, cameras, lights and an electric release to separate the GML from the launcher.

The bi-directional video and data telemetry provides online video transmission, power supply and surface control of various relay functions. At present, three telemetry systems are used to deploy landers in various projects/settings from different research vessels. Whereas the coaxial telemetry provides only black and white video transmission for one camera, the fibre optic telemetries provide two colour video channels per laser module.

"In the future, landers will also be incorporated as modules into glass-fibre optical cable systems spanning whole continental margins. "

The launcher carries up to two video cameras, a survey camera in the front and a downward-orientated camera showing the lander during deployment. Both cameras and floodlights can be switched on and off with a PC-controlled telemetry surface unit. Additionally, the launcher is designed to carry a scanning sonar with online data transmission to the surface to scan a broader field for acoustic objects (e.g., precipitates, clam fields, gas emissions, obstacles) than can be obtained by the video cameras.

The whole system is towed approximately one metre above the seafloor, and the height is adjusted by the winch operator. For navigation purposes, a transponder is mounted close to the instrument on the cable using either long base line or ultra-short base line navigation. The launcher enables accurate positioning on metre scale, soft deployment, and instantaneous disconnection of the lander and launcher by an electric release that is activated by electric command of the operator through the telemetry unit.

Scientific Payload

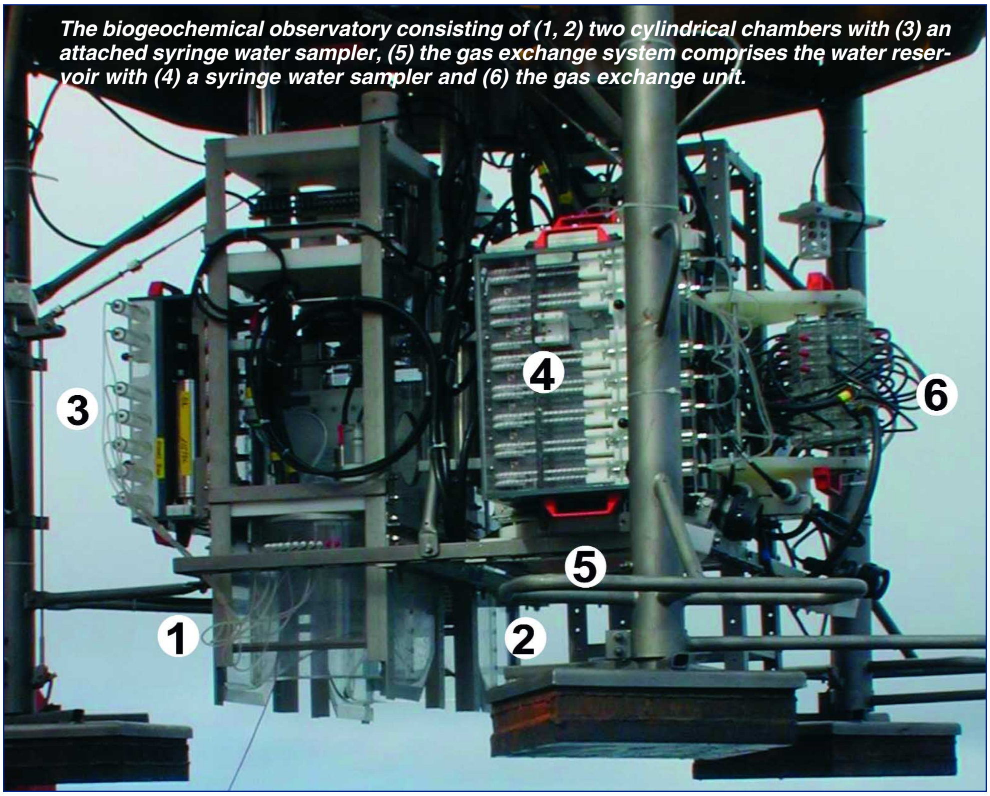
The GML provides the platform for GEOMAR's present research activities, but carrying guest experiments from scientific partners is also common practice. The constructional characteristics of the GML offer the potential for fundamental and applied deep- water studies.

The present GML application addresses integrated benthic boundary layer current measurements, quantification of particle flux, quantification of gas flow from acoustic bubble size imaging, monitoring of mega-benthic activity, fluid and gas flow measurements at the sediment-water interface, biogeochemical fluxes at the sediment-water interface (oxidants, methane, nutrients), experiments with deep-sea sediment and organisms (food enrichment, tracer addition, change of physical and chemical environmental parameters) and gas hydrate stability experiments.

The GML is employed both as a carrier for commercially available oceanographic equipment in various configurations and GEOMAR-designed benthic observatories. Standard payload equipment includes acoustic Doppler current profilers (75, 300 and 1,200 kilohertz); current meters; conductivity, temperature, depth instruments; a stereo deep-sea camera system; a multibeam echo sounder; sediment traps (conical and triplet cylinder); and syringe water samplers.

A focus of GEOMAR observatory development is benthic

The biogeochemical observatory consisting of (1, 2) two cylindrical chambers with (3) an attached syringe water sampler, (5) the gas exchange system comprises the water reservoir with (4) a syringe water sampler and (6) the gas exchange unit.



chamber systems to measure material fluxes and fluid flows at the sediment-water interface and to perform *in-situ* experiments with deep-sea benthic communities. Benthic chambers (squared or cylindric) are supported by a stainless-steel frame that is mounted to the GML platform. Each chamber represents an autonomous module with its own control unit and power supply with rechargeable NiCd battery packs integrated into a glass sphere. Chambers are driven into the sediment by a motor approximately two hours after reaching the seafloor. After implementation of the chamber, the top lid is closed. At the end of each incubation, a shutter is closed by a second motor in order to retrieve the sediment. Once the shutter is closed, the chamber is slowly withdrawn from the sediment by the first motor, and the lander can be called back to the surface. All maintenance-free drive units are standard DC motors in stainless-steel pressure housings.

Recent development toward a biogeochemical observatory (BIGO) in a cooperative project with the Technical University of Hamburg-Harburg (with Prof. G. Gust) will employ a "Gust mesocosm" as a chamber lid. This stirring device either reproduces the ambient outside current regime or alters bottom shear stress for experimental designs.

In order to record long-term variability of benthic turnover in semi-closed chamber systems, it is of crucial importance to maintain the oxygen supply at natural levels and to avoid severe oxygen depletion. Thus, to compensate for the total oxygen consumption of the enclosed sediment community, a gas exchange system was developed. This system facilitates a controlled oxygen transfer from a reservoir containing oxygen-saturated seawater into the benthic chamber. A particle and fluid injector is employed for experimental designs to add organic substances and liquid or particulate tracers. This approach represents a major step toward the development of deep-sea experiment systems and from stationary to dynamic benthic chambers.

Another novel development within the long-term observatory for the study of control mechanisms for the formation and destabilisation of gas hydrates (LOTUS) programme is the Fluid Flux Observatory, which was designed by the Technical University of Hamburg-Harburg (by S. Gubsch and T. Viergutz) to measure and differentiate between gaseous and aqueous fluxes and the direction of very small fluid flows from cold seep settings.

"Lander systems are now used as platforms for a wide spectrum of oceanographic applications."

Further Applications

With the growing need for long-term seafloor observatories, as presently outlined in the European Union's European Seafloor Observatory Network programme,[6] the lander will play a vital role. Targeted deployed landers with a wide range of instruments and sensors for physical, chemical, biogeochemical and biological parameters will be employed in a single autonomous mode in relatively inaccessable terrains (high latitudes, central parts of the oceans, canyons, mid-ocean ridges, fracture zones). Typical observation periods will be one to two years. Bi-directional communication with the lander was recently introduced by using an acoustic link through a modem. The transmission rates and data quality, however, are still hampered by the baud rate of the modems.

In the future, landers will also be incorporated as modules into glass-fibre optical cable systems spanning whole continental margins. While large glass-fibre optical cable networks represent a major investment and remain stationary for decades, lander clusters connected by optical cable represent a cheaper and highly mobile alternative. Such networks can be moved and used in a task force mode for current problems such as global change and environmental monitoring. Clustered lander systems should transmit data to the surface and further by satellite link to the shore. The lander arrays can consist of diverse lander-types for scientific observation, power supply and garage-types for small autonomous (AUVs and crawlers) and tethered vehicles (ROVs).

Acknowledgements

The development of the GML and associated scientific modules was achieved by the dedicated support of the members of our working group, namely the project engineers V. Nuppenau, F. Appel, A. Cremer, M. Poser, M. Pieper; the technicians A. Petersen, W. Queisser; and the scientists Dr. U. Witte and Dr. S. Sommer. This work has been funded by the German Federal Ministry of Education and Research (BMBF) as part of the projects BIO-C-FLUX, BIGSET, TECFLUX and LOTUS, and by the European Union as part of the project ALIPOR.

This is publication GEOTECH-29 of the progam GEOTECHNOLOGIEN of the BMBF and the Deutsche Forschungsgemeinschaft (DFG).

References

For a full list of references, please contact the author Olaf Pfannkuche at opfannkuche@geomar.de. /st/

Olaf Pfannkuche obtained his master's degree in biology in 1973 and his Ph.D. in 1977, both at the University of Hamburg. Since 1993 he worked at GEOMAR. Pfannkuche has a record of 25 years of scientific work in the deep sea and participated in more than 50 sea-going expeditions. His research activities deal with carbon cycling, benthic ecology, biogeochemistry of cold seeps and marine gas hydrate deposits, risk assessment of mining activities and waste disposal in the deep sea. He, together with Peter Linke, received the K.E.R.N Award for the development of advanced lander technology in 2001.

Peter Linke is a marine biologist and started his scientific work in 1985 on bentho-pelagic coupling within the Sonderforschungsbereich 313 at Kiel University. There he got his Ph.D. in 1989 and joined GEOMAR in 1993 as a senior scientist to investigate the biogeochemical processes that are associated with fluid flow phenomena at various subduction zone and hydrothermal vent settings. He worked as principal investigator in several European Union projects and various nationally funded projects. He, along with Erwin Suess, Gerhard Bohrmann, Jens Greinert and Dirk Rickert, received the Philip Morris Award for research on marine gas hydrates in 2001.